An Aerospace Nation

Aerospace is deeply connected to US identity—its power and place in the world. Progress in aerospace opened doors to new methods of travel, economic prosperity, and the means to shelter and defend the nation. However, the rapid development of aerospace power was not something left to chance. Such an achievement was a national priority—one that called together all aspects of American society. Military experts worked closely with civilian engineers to refine requirements; academics contributed to designs, while machinists worked with designers. This kind of collaboration formed the United States as an aerospace nation, and aerospace industries remain critical to the US economy, the American people, and the American way of life. Now is the time to consider a short historical view of the impact aerospace has had on the United States and also to warn about the costs of neglect. More importantly, the nation must have a new vision for the future of aerospace.

The Rise of the Aerospace Nation

During the middle of the twentieth century, the US aerospace industry grew tremendously, resulting in the United States emerging from World War II with the world's most advanced commercial infrastructure and preeminent economy and as the world's only nuclear super power.[1] This industry created the foundation upon which the US economy rests and continued to ingest heavy investment for several decades—while providing a major source of American power.[2] In addition to doubling human productivity, becoming an aerospace nation was a critical pillar of economic growth for the United States.[3] Doing so allowed the United States to reap dividends in defending the nation's interests. Capabilities developed by advances in aerospace enabled reduced defense spending as a result of our technological asymmetric advantage. These "offset" reductions in defense spending allowed for development elsewhere in the US economy.

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The first offset resulted from rapid advancement in the key areas of propulsion, aerodynamics, flight controls, avionics, and human factors that were achieved in the 1950s and beyond. America, as an aerospace nation, served as the essential integrator for these technologies. The aerospace community united for the "first offset strategy" of integrating nuclear warheads on bombs and missiles, which enabled Pres. Dwight Eisenhower's "New Look" strategy—cutting the defense budget by 40 percent between 1952 and 1956. The United States relied on its aerospace superiority to offset Soviet military might without sacrificing the security of our nation or commitments to allies and partners.[4]

The second offset resulted from technological investments in sensing; precision navigation and timing; intelligence, surveillance and reconnaissance; and stealth technologies. Again, US supremacy in the aerospace arena enabled smaller numbers of weapons to be used to hit and destroy key military targets. These investments enabled lower procurement numbers of advanced platforms, saved billions of dollars, and kept the United States ahead of the rest of the world as an aerospace nation.[5]

The payback to the economy and to the taxpayers from these aerospace investments remains significant. Today, this industry—from private aircraft manufacturers, to general aviation, to commercial space—produces $118.5 billion in export sales for the United States, results in approximately $370 billion in domestic aerospace purchases, and employs or supports more than 1.849 million people, whose spending employs 2.51 million more. The aerospace industry is the fifth-largest contributor to the gross domestic product (GDP) of the United States, behind only health care, chemicals, the food industry, and information technology.[6] Of these five, only the food industry also produces a positive export balance for the United States, making the aerospace industry a key component of balancing US foreign trade.[7] It contributes to America's ability to "respond to threats such as terrorism, environmental disasters, and pandemics."[8]

In addition, there are new technologies and businesses that emerge as a result of aerospace investments. Each year, NASA publishes a book called *Spinoff* that highlights its return on investment, often estimated to be several dollars of impact for every dollar spent.[9] Small samples of the job-creating technologies that have emerged from these investments include the following:

- Filtration systems that have brought cheaper and more accessible drinking water to millions throughout the world
- Bioreactors that sparked creation of a new multimillion dollar line of healthy organic juices[10]
- Insulating aerogels that create more durable outerwear from the materials that keep our astronauts insulated from the extremes of space (these same gels are also now being used in building materials improving energy conservation)[11]
- New coatings that increase solar collector efficiency
- Antigravity treadmills developed to train astronauts that are now being used to rehabilitate patients with serious arm and leg injuries.

There are numerous industries that boost our economy and improve our quality of life that emerged from US aerospace investments. Despite these successes, America cannot take this source of technological innovation for granted.

The Cost of Neglect

The story of America's rise to become an airfaring nation is a proud one, but the gains won by hard work are quickly being lost. The status of nation-states can rise and fall quickly. For example, in 1900, Great Britain was the richest nation in the world. Boasting the planet's most powerful military, Britain was the center of world commerce, information, and finance. Its education system was second to none, and its currency was the world's benchmark. In the early part of the twentieth century, the British Empire covered one-fifth of the world's territory and included a quarter of the world's population. Yet four decades after the declaration of the Aerial League of the British Empire, that prominence crumbled and the era in which Britannia ruled the seas gave way to "the American Century."[12]

A similar shift is now under way in the United States. A former chief executive officer (CEO) of American Airlines lamented, "[We are] now laggards in every category."[13] Once we were visionaries, and integrated aerospace was a core cultural, industrial, intellectual, and even aspirational tenet of American power. Now, America has atrophied from its natural curiosity and the frontier of discovery.

Today, the average citizen's experiences with aerospace are no longer inspirational; they are mundane and tired. In 2014 none of the top 25 airlines were American.[14] A far cry from the ambition of Pres. Harry Truman and Gen Jimmy Doolittle, our airports also lag. As of March 2015, the United States had no airports in the world's top 25, and 19 nations had superior airport infrastructure to the top-rated American airport in Cincinnati. Our newest airport, Denver International, the multibillion dollar five-year construction project that concluded with a malfunctioning luggage system, came in second in the United States and 37th place in the world.[15] Meanwhile, nations such as China build new aviation facilities more quickly and to a higher standard than we do. China is planning to spend the equivalent of $250 billion building their aerospace industries of the future and is the site of over two-thirds of the airports now under construction around the world.[16] Beijing International, completed in half the time of Denver,[17] is one of the world's top-10 airports and handles seven times the passengers of Denver International.[18] In some Chinese cities, the airport developers are being advised by a leading American proponent of the airport-centered city, or "aerotropolis."[19]

Thus, it is no surprise so many in America seek their dreams and employment outside the aerospace sector.[20] Tech savvy Millennials gravitate to Silicon Valley not Palmdale, California, or Dayton, Ohio. Aviation innovation in America seems on laissez faire–neglect autopilot, disconnected from national goals and policy that nurtured it and America to greatness. While 600 million people watched Apollo 11 landing on the moon, only 11,000 watched SpaceShipOne win the $10 million Ansari XPRIZE.

Loss of Competitiveness in Aerospace

In the critical area of space, the United States is losing market share. It fell from being the dominant space power with 31 new satellite orders—more than 54 percent of the world's total in 2008—to only 32 percent of global orders in 2013 and only 11 new satellite orders in 2014. This represents a 22-percent loss in world share in only five years.[21] The situation is no better in airplane manufacturing. US competitiveness, which is already eroding compared to European competition, appears about to erode further—damaging a major component of

the US economy. Total employment in the aircraft portion of the aerospace industry has declined almost 20 percent from a peak of 741,100 in 1998 to only 606,000 today.[22] Airbus consistently challenges Boeing as the world's principal airline platform, while China—able to undercut both American and European wage structures—has just entered the market.[23] Without bold leadership and deliberate revitalization, US market share is likely to decline further. The new Chinese manufacturer, Commercial Aircraft Corporation of China (Comac), has already won 400 orders for its C919 airliner, an aircraft in the same large commercial class as the Airbus A320 and Boeing 737. This number is roughly equivalent to an entire year's large aircraft order share of Boeing or Airbus in recent years.[24]

America's leadership in the high-technology sector is also faltering and, if not corrected, will put downward pressure on our economy. Of the 50 advanced industries, aerospace is one of only nine that are contributing to reduced trade deficits. It is also the largest of these industries in its contribution to the US balance of trade. Yet, in high-tech jobs, America is declining. The share of advanced technology jobs in the United States lags behind the Czech Republic, Slovenia, Germany, Hungary, Sweden, Finland, Italy, Denmark, and Austria. Further, with one of the steepest rates of decline in these sectors in the developed world, the United States is poised to fall behind France, the Netherlands, Norway, and Belgium over the next several years.[25]

A lack of people educated in science, technology, engineering, and math (STEM) in the workforce is part of the US problem. In 2013 a Price Waterhouse Cooper survey of CEOs found that 54 percent of aerospace companies view the lack of available skills as the most significant threat to company growth. Other nations are graduating more engineers and hard-science professionals than the United States. An estimate by the US Department of Commerce predicts that by 2018 "the U.S. will have more than 1.2 million unfilled STEM jobs because there will not be enough qualified workers to fill them."[26] Reviving the aerospace nation begins with recapturing the magic and mystique of the first decades of aerospace innovation for our youth. If the United States fails to motivate the new generation to become part of something more and if it fails to attract the technicians and engineers to make a difference in its high technology industries, the US decline relative to other

states will continue, causing the American Century to give way to the Asian Millennium.[27]

Being an aerospace nation has paid vast dividends to the US economy in the past, and it can again. Beyond creating more than 4 million jobs tied to aerospace, investments in these industries help create a better life for Americans. In 2014 NASA estimated technology it originally paid for and developed saved 449,850 lives (equivalent to the entire population of Atlanta), created nearly 19,000 jobs (the approximate seating capacity of Madison Square Garden), generated $5.2 billion in revenue for commercial companies (or more revenue than for all concerts held in North America), and reduced the costs of living for Americans by $18.6 billion (more than the total revenue for the global airline industry).[28]

Investments in these enterprises reap great rewards, and American investment in aerospace has never failed to pay off. The aerospace investments made in 2010 returned $37.8 billion in tax revenue to the US treasury in that year alone.[29] Most of these investments will continue to pay additional dividends in the years that follow or generate spinoff companies that will pay future dividends to the taxpayer as these nascent businesses and industries grow. While precise estimates vary based on specific study methodology and the timeframe analyzed, the dollars invested by the government in the aerospace industry have created large numbers of private-sector jobs and spinoffs, with a return to the treasury that is well over one dollar of tax revenue for each dollar spent, making the aerospace industry one of the few places where increased government spending actually makes money for the taxpayer.[30] Thus, being an advanced aerospace nation will help balance the federal budget and extend the benefits of prosperity to a new generation. What the United States needs now is a vision of where aerospace could take it and a strategy to get there.

A Vision for the Future

The United States can reinvigorate its aerospace industry into a globally admired enterprise that again becomes the engine for innovation, business development, and commerce for the nation. However, this will require the combined efforts of all its citizens: engineers, industry, academia, and the military. While we have a model on which this was

done under the stress of nuclear and space competition in the 1950s, a broader model is needed now.[31]

In 1946, to help the aerospace industry grow, President Truman issued Executive Order 9781, establishing the Air Coordinating Committee, with the mission to "examine aviation problems and development affecting more than one participating agency; develop and recommend integrated policies to be carried out and actions to be taken."[32] Through interdepartmental cooperation between the Departments of State, War, Navy, Commerce; the Post Office; and the Civil Aeronautics Board, the United States created the airspace structure that became the model for the world and created a vision for space activities that would enable that nation to compete in the space race. Today, with a broader range of challenges before us, a similar but broader construct is needed.

Therefore, the United States must establish a National Aerospace Coordination Council. This council would be responsible for providing the interagency coordination required to implement the National Aerospace Strategy. Responsible directly to the president, the council should—at a minimum—be comprised of representatives from NASA, the Federal Aviation Administration, the White House Office of Science and Technology, and the Departments of Education, Commerce, Energy, Homeland Security, and Defense to coordinate and implement the steps governing the reinvigoration of our STEM education and aerospace infrastructure enterprises. This council should also be infused with—or regularly consult—the captains of the aerospace industry. Its central role will be to enable a path forward whereupon innovation, commerce, logistics, and new scientific breakthroughs can be accelerated using all forms of aerospace technology, including robotics, drones, information technologies, energy research, and aerospace design.

Establish a New Air and Space Structure

Like its predecessor, this council will, as one of its deliverables, define an airspace utilization plan for the twenty-first century. This plan needs to accommodate large fleets of unmanned vehicles that may deliver goods and services transiting the national airspace, potentially in close proximity to aerodromes, while operating autonomously and outside the line of sight of any human director. This construct needs to accommodate logistics paradigms, such as drone delivery of goods and services to one's doorstep—as well as transit from the existing airspace structure

to and from space.[33] Once developed, this system should be promulgated to the International Civil Aviation Organization for international implementation.

Double Down on Far-Term Investments

This council will be empowered to coordinate research efforts into aerospace technologies to coordinate the movement of aerospace advancement across the spectrum. Investments by the Department of Education and Department of Defense laboratory system, the Defense Advanced Research Projects Agency, and the National Oceanic and Atmospheric Administration can be leveraged cooperatively to move forward new aerospace structural concepts, including the blended-wing body and new engine designs like the Air Force's Adaptive Versatile Engine Technology (ADVENT) program or NASA's Environmentally Responsible Aviation project. With industrial representation, these breakthroughs can be shared with the captains of US industry, enabling these leaders to market breakthrough technologies that will enhance their market share of emerging and new business opportunities. Within this investment portfolio, the council will ensure basic science and technology research with an eye toward the future. At present, these investments represent a very small fraction of the research enterprise; thus, increasing these investments carries little cost. Nonetheless, seed money for technologies such as extraction of minerals from celestial bodies, diversion of asteroids from Earth orbit or collision, and efficient power collection and storage in space are among the spacefaring capabilities that should serve as a guide for longer-term investment.

Begin a New Series of Innovation Prizes

New technologies will be required across the aerospace spectrum, ranging from the control of unattended drone delivery of goods and services to establishing new capabilities in space. To this end, the government—alongside the private sector—should incentivize the collective engineering intelligence of the nation by creating a series of "X-Prizes" for breakthroughs in key technologies. Among those that may need emphasis are precise navigation and timing and applied autonomy technologies. The council will work to ensure these competitions are aimed at and designed to develop and implement the national aerospace utili-

zation promise outlined above and to enable the exploration of space as described below.

Increase Tolerance for Risk and Adventure

The United States needs a renewed commitment to innovation and to risk. Research involving science and technological risk is critical to advancing the aerospace industry and creating new spinoff technologies and businesses that create jobs for America. Research involving little or no risk pays little or no dividends, and if we are not occasionally failing in attempts to push the science-and-technology envelope, that means we are not trying.[34]

As Pres. John F. Kennedy said in 1962, "We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills."[35] As President Kennedy articulated, the nation needs lofty goals. Therefore, the council will, as it directs the research and development spending, deliberately vector some of this funding to projects that may fail—and may even do so spectacularly. However, such failures teach us how to get the hard science right the next time. Thus, failing early, often, and sometimes even loudly needs to be an accepted cost of engaging in leading-edge research.[36]

Create a New National Aerospace Infrastructure Plan

The council will explore national aerospace infrastructure needs, including airspace, routing, and terminal facilities for both air and space travel. Development of innovative facility design to ensure proper passenger and commercial shipment security while providing world-class experiences for passengers will be a major priority. To instill a sense of wonder in aerospace, flying by the general public must again be a wondrous experience. The council should give consideration to leasing or sharing arrangements with existing government aerospace infrastructure, including the space-launch facilities in Florida and California. Arrangements that enable commercial exploration and experimentation in and through the aerospace domain should be a priority. Integration of privately developed air and space ports into the national aerospace infrastructure should also be undertaken.

Prioritize National Science Activity

The council will be charged with enhancing STEM education across the United States. Partnering with our best engineering institutions and with industry, the council will coordinate joint private/public-funded scholarship opportunities to create an incentivized pathway for 1.5 million secondary students to obtain STEM degrees.[37] Those who take these scholarships would study in defined degree areas and then pay back their scholarship by working either for the government agencies and/or the private companies that funded their education, thereby addressing the STEM shortage.[38] This coordination would allow for targeted recruiting by government and industry of desired skill sets, diversity, and the technological breadth that would optimally move the aerospace sector forward.[39] This initiative would more than pay for itself. The advanced industries that have grown out of our STEM investments to date will add $2.7 trillion to the US GDP—or about 17 percent of the total this year.[40]

Prioritize Space Development and Set Ambitious Goals

The council will take for action the consensus recommendation of NASA's 2015 Pioneering Space National Summit. The joint statement of the approximate 100 attendees was that "the long term goal of the human spaceflight and exploration program of the United States is to expand permanent human presence beyond low-Earth orbit in a way that will enable human settlement and a thriving space economy. This will be best achieved through public-private partnerships and international collaboration."[41] While not fully implementable in the next 20 years, the council will lead a public-private partnership to begin to solve the key challenges in space. America needs to be the first nation to establish a propellant depot in space, the first to conduct space refueling, the first to mine the moon or harvest asteroids, and the first to construct a permanent settlement in space.

Invest in Promising Technologies

Lastly, the council will leverage the best scientific and strategic minds across the government enterprise to explore whether a new synergistic use of emerging technologies may enable new strategies to defend the homeland across the interwoven dimensions of land, sea, air, space, and

cyberspace, while projecting power around the globe. Investments in power, propulsion, and sensors have historically paid dividends. New technology vectors such as autonomy, swarming, directed energy, independent precision navigation, and timing are all showing rapid advances toward potential breakthroughs. Specifically, the council will pursue a portfolio development approach to explore whether the ability to network myriad small systems with larger systems into a seamless but massed force could enable the military to conduct operations in ways never before envisioned. A true third offset will be more than about airplanes or new computers. It will depend on people and require the United States to maintain its aerospace technology leadership over all competitors—a lead we are not guaranteed to maintain. It requires the United States to again bring engineers, academics, business leaders, and government together as an aerospace nation.

Conclusion

The widespread benefits of aviation did not just happen. They were the result of deliberate strategy by both civilian and military thinkers who understood the far-reaching value of aviation in a time when American leadership was shaping the institutions of the world and the industrial policy at home. Over the next 20 years the United States will open the door to the markets of the 3 billion people in the developing world. It will develop a method of coordination of lower airspace infrastructure in a manner that enables safe and efficient transportation of materials by drone or other robotic devices from any place to anywhere. The country will reinvent its domestic aerospace infrastructure such that it leads, not lags, the world. It will create new engine designs based on programs such as the ADVENT and Environmentally Responsible Aviation research efforts that will improve fuel efficiency—potentially making the United States the engine supplier of choice for the world—while reducing costs of travel for passengers and logistics alike.[42] It will create new blended-wing body aircraft that will be more aerodynamic and more efficient, enabling airlines and logistics to be conducted more efficiently with designs that no other country can match.[43] The nation will invigorate light-aircraft manufacturing to become the chief suppliers of small aircraft for emerging air service routes in areas such as the awakening countries of Asia and Africa.[44] It will set sights on rekindling

spacefaring interests to expand not only exploration but also exploitation of resources that exist in space. The country will enable commercial interests to begin ventures that explore and profit from the vast mineral and power resources that lie on the moon and within earth orbit, while developing systems that can mitigate the risk from asteroid strikes.[45] The United States will do all these things while ensuring the fiscal security of the nation and maintaining our commitments to the American people and allies.

The world is again at a place where US leadership can make a difference. It is again at a place where aerospace vehicles can change the world for the better and where the nation's grand strategy is an aerospace strategy. The recipe for success has not changed: first, have a vision for shaping the aerospace domain, and second, invest in preeminence in aerospace transportation. The future of the United States as an aerospace nation hangs in the balance. We are best as an aerospace nation when our brightest minds, our most innovative industries, and our most critical governmental agencies work together. The future economic prosperity and national security depend on the choices we make now. The steps outlined above form the initial vector to put America back on a trajectory that will lead us higher and farther and extend the blessings of liberty and prosperity to ourselves and our progeny. SSQ

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Notes

1. The US economy grew by 50 percent in the 1940s alone, from $200 billion in 1940 to roughly $300 billion in 1950. However, US dominance as the world's only nuclear power was short-lived. Christopher Conte and Albert R. Karr, *An Outline of the U.S. Economy* (Washington, DC: US Department of State, 2001), http://usa.usembassy.de/etexts/oecon/chap3.htm.

2. Alexander J. Field, *The Great Leap Forward: 1930s Depression and U.S. Economic Growth* (New Haven, CT: Yale University Press, 2011), 1–9. Field argues that the transformational period of transportation, to include land and air, resulted in the highest period of total factor productivity growth in American history from 1928 to 1950. He credits the transportation network, to include aviation, with this dynamic—in what he calls "The Most Technologically Productive Decade of the Century." In the interest of precision, Field argues that the demilitarization of the United States and the failure to invest in aviation technology during

the 1930s was counterproductive in terms of economic growth until 1941, by which time military research and development were again a significant aspect of economic development and human productivity growth.

3. The US economy grew by 50 percent in the 1940s alone, from $200 billion in 1940 to roughly $300 billion in 1950. However, US dominance as the world's only nuclear power was short-lived. Christopher Conte and Albert R. Karr, *An Outline of the U.S. Economy* (Washington, DC: US Department of State, 2001), chapter 3.

4. Zachary Keck, "A Tale of Two Offset Strategies: The Pentagon's New Offset Strategy Is Modeled on Two Very Different Historical Examples," *The Diplomat* (Japan), 18 November 2004, http://thediplomat.com/2014/11/a-tale-of-two-offset-strategies/.

5. Ibid.

6. US Department of Commerce, "The Aerospace Industry in the United States," *SelectUSA* (web site), no date, http://selectusa.commerce.gov/industry-snapshots/aerospace-industry-united-states. The recent Deloitte study on employment in the aerospace industry augment the numbers in this study for employment. See also Deloitte (firm), *The Aerospace and Defense Industry in the U.S.: A Financial and Economic Impact Study* (New York: Deloitte, March 2012), 1–3, 16–19, 22, https://www.aia-aerospace.org/assets/deloitte_study_2012.pdf.

7. The Foreign Trade Division of the Census Bureau reports trade statistics through its publications and USA trade online portal. This represents Deloitte analysis of these statistics. Ibid., 21, 78.

8. Mark Muro, Jonathan Rothwell, Scott Andes, Kenan Fikri, and Siddharth Kulkarni, *America's Advanced Industries: What They Are, Where They Are, and Why They Matter* (Washington, DC: Brookings Institute, February 2015), 14, http://www.brookings.edu/~/media/Research/Files/Reports/2015/02/03-advanced-industries/final/AdvancedIndustry_FinalFeb2lores.pdf?la=en.

9. Several studies have looked at the return on investment to the economy of aerospace nation developments. In 1971, Roberts and his peers found the return on investment from NASA research in the 1960s and 1970 to be $7.24 for every dollar spent. See Robert E. Roberts, Howard M. Gadberry, Robert E. Fleisher, Lawrence L. Rosine, E. Duane Dieckman, and Linda L. Crosswhite, *Economic Impact of Stimulated Technological Activity* (Kansas City, MO: Midwest Research Institute, November 1971), http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19730012250.pdf. These numbers do not count computing advances or the information technology sector, some of which resulted from spinoffs of previous NASA, ARPA, and military investments. More recently, numbers of around 5:1 continue to be found. See Henry R. Hertzfeld, "Measuring the Economic Returns from Successful NASA Life Science Technology Transfers," *Journal of Technology Transfer* 27, no. 4 (December 2002): 311–20. For an up-to-date list of recent NASA technology impacts on business, see National Air and Space Administration, *Spinoff*, 2015, 11, https://spinoff.nasa.gov/flyers.html.

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was the first to use the term *American Century*. See his article, "The American Century," *Life Magazine* 10, no. 7 (17 February 1941): 61–65.

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14. The Skytrax World Airline Awards are the result of surveys from 19 million travelers from around the world. The airline industry recognizes this annual award as a "benchmark of Airline Passenger Satisfaction levels." See "Top 100 Airlines," *World Airline Awards* (web site), 2015, http://www.worldairlineawards.com/Awards/world_airline_rating.html. The top-rated US airlines were Virgin Atlantic, which came in 47th place in the world; Delta, which was 50th; and United, which was 53rd.

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21. Data source is the Satellite Industry Association Statistics for October 2013, 2010, and 2008, http://www.sia.org;; and Garber, Hanna, and Ateshkadi, *California Aerospace Industry Economic Impact Study Final Report.* See also Tauri Group, *State of the Satellite Industry Report* (Washington, DC: Satellite Industry Association, September 2014), 24, http://www.sia.org/wp-content/uploads/2014/09/SSIR-September-2014-Update.pdf. Reader should note that part of the decline in the number of satellite orders for 2014 is due to uncertainty in Russian launch capacity caused by the conflict in Ukraine. See Tauri Group, *State of the Satellite Industry Report* (Washington, DC: Satellite Industry Association, May 2015), 25, http://www.sia.org/wp-content/uploads/2015/06/Mktg15-SSIR-2015-FINAL-Compressed.pdf.

22. "Total Employment," Aerospace Industrial Association (web site), 2015, http://www.aia-aerospace.org/assets/Stat_Series_12_Employment_-_2014.pdf.

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27. This term was coined in the *Air Force 2025 Study*. See Joseph A. Engelbrecht Jr., Robert L. Bivins, Patrick M. Condray, Merrily D. Fecteau, John P. Geis II, and Kevin C. Smith, "Alternate Futures for 2025: Security Planning to Avoid Surprise" (research paper, Maxwell AFB, AL: Air University Press, April 1996), 79–89, http://www.au.af.mil/au/awc/csat/2025/a_f.pdf. Discussions in the study relevant to the economic competitions are found on 29–30, 34, 45–47, 49–52, 59–61, and 163–97.

28. NASA, "Spinoff" (PowerPoint presentation, NASA, 2015), slide 53, http://spinoff.nasa.gov/Spinoff2015/PowerPoint/Spinoff2015.pptx.

29. Deloitte (firm), *The Aerospace and Defense Industry in the U.S.*, 19.

30. Several studies on NASA and aerospace industry return on investment have been accomplished over the years. Estimates of return on investment are very sensitive to the statistical assumptions made in the analysis. For concerns on the sensitivity of the assumptions to the precise ratio, see Henry R. Herzfeld, *Measuring the Returns to NASA Life Science Research and Development* (Washington, DC: Space Policy Institute, George Washington University, 30 September 1998), and Ken Chamberlain, "Measuring the NASA Stimulus," *National Journal*, 27 August 2010, http://www.nationaljournal.com/njonline/no_20100827_1798.php. The general range of these estimates is between 7:1 and 14:1. See Lauren Lyons, "5 Popular Misconceptions about NASA," *Huffington Post*, 9 September 2013, http://www.huffingtonpost.com/lauren-lyons/misconceptions-nasa_b_3561205.html.

31. Delbert R. Terrell, *The Air Force Role in Developing Outer Space Law* (Maxwell AFB, AL: Air University Press, May 1999), http://www.au.af.mil/au/awc/awcgate/space/terrill.pdf.

32. Harry S. Truman, "Executive Order 9781 – Establishing the Air Coordinating Committee, September 19, 1946," *American Presidency Project* (web site), no date, http://www.presidency.ucsb.edu/ws/?pid=77956.

33. For one such logistics construct, see the "Amazon Prime Air," *Amazon.com*, 2015, http://www.amazon.com/b?node=8037720011.

34. Vanessa Chan, Marc de Jong, and Vidyadhar Ranade, "Finding the Sweet Spot for Allocating Innovation Resources," *McKinsey Quarterly*, May 2014, http://www.mckinsey.com/insights/innovation/finding_the_sweet_spot_for_allocating_innovation_resources.

35. John F. Kennedy, "Text of President John Kennedy's Rice Stadium Moon Speech," *NASA.gov*, 12 September 1962, http://er.jsc.nasa.gov/seh/ricetalk.htm.

36. "I want Americans to win the race for the kinds of discoveries that unleash new jobs—converting sunlight into liquid fuel; creating revolutionary prosthetics, so that a veteran who gave his arms for his country can play catch with his kid; pushing out into the Solar System not just to visit, but to stay." Pres. Barack Obama, "State of the Union Address – January 20, 2015," https://www.whitehouse.gov/the-press-office/2015/01/20/remarks-president-state-union-address-january-20-2015.

37. Some of these steps were proposed in the president's FY 2014 budget. See "Fact Sheet: A Better Bargain for the Middle Class: Jobs," The White House, 30 July 2013, http://www.whitehouse.gov/the-press-office/2013/07/30/fact-sheet-better-bargain-middle-class-jobs; and Advanced Manufacturing National Program Office, "NNMI [National Network for Manufacturing Innovation] Snapshot," *Advanced Manufacturing Portal*, 2015, http://manufacturing.gov/nnmi.html.

38. Ibid. Previous studies have indicated that the outcome of such an initiative could be the creation of a set of innovation hubs, as industry selects schools to specialize in their requirements and then fund scholarships to these locations to produce their future workforce.

39. Muro, Rothwell, Andes, Fikri, and Kulkarni, *America's Advanced Industries*, 1–3. These researchers count among the advanced technology industries all those in which research and development exceeds $450 per employee; foremost among these industries is aerospace products and parts.

40. Ibid., 3–5. In addition, the value added to the economy of those who are employed in advanced technologies is over $210,000 per person—more than any other economic sector.

41. "Statement of the Participants of the 2015 Pioneering Space National Summit," *NASA.gov*, 26 February 2015, http://www.nasa.gov/content/pioneering-space-national-summit-2015/.

42. Stephen Trimble, "Full ADVENT Engine Tests meet Fuel, Heat Goals: GE," *Flightglobal* (web site), 21 January 2015, http://www.flightglobal.com/news/articles/full-advent-engine-tests-meet-fuel-heat-goals-ge-408182/. GE's latest tests show an improvement in engine efficiency of approximately 35 percent. Similarly, NASA's Environmentally Responsible Aviation program is looking at innovative concepts in propulsion that will not only reduce engine pollution but also enhance aircraft efficiency from both platform and propulsion standpoints. See "Environmentally Responsible Aviation Project," *NASA.gov*, 7 August 2015, http://www.aeronautics.nasa.gov/iasp/era/index.htm.

43. NASA, the Air Force Research Laboratories, and the Boeing Phantom Works are testing a blended-wing body demonstrator, the Boeing X-48C. Michael Braukus, Gray Creech, and Tom Koehler, "Release 12-259: Transformed X-48C Flies Successfully," *NASA.gov*, 7 August 2012, http://www.nasa.gov/home/hqnews/2012/aug/HQ_12-259_Transformed_X-48C_Flies.html#.VQikCf50zxg. NASA's ongoing efforts continue to develop a new aircraft design that is much more fuel efficient and will likely achieve success in the near term.

44. While not an exhaustive list, companies such as Cessna, Piper, and Gulfstream are among those whose aircraft size may be optimum for small, nascent emerging markets. In the area of utility aircraft, companies such as Air Tractor may be a key supplier of utility and agricultural aircraft to these same parts of the world.

45. Olga P. Popova, Peter Jenniskens, Vacheslav Emel'yanenko, Anna Kartashova, et al., "Chalyabinsk Airburst Damage Assessment, Meteorite Recovery, and Characterization," *Science*, 342, no. 6162 (29 November 2013): 1069–73, http://www.sciencemag.org/content/342/6162/1069.